**Investigation of the Magneto-Acoustic Villari Effect for Measuring the Internal Stress in Composites**

**Investigator(s):** Dr. Eric Madaras and Dr. Michael Horne

**Purpose**

The purpose of the proposed research is to develop a novel self-sensing material based on the ability to detect the acoustic response of the inverse magnetostrictive effect that is activated by high strain. The self-sensing material is to be created by embedding magnetostrictive material in composite laminates

**Background**

Our hypothesis is that monitoring the acoustic response of stressed magnetostrictive particles embedded in a polymer composite will allow subsurface nondestructive stress measurements. This has heretofore been unattainable without embedding strain gages. High frequency magnetic noise (Barkhausen Acoustic Emissions (BAE)) or lower frequency magnetic noise (Magnetic Acoustic Emissions) (MAE)) created during low frequency sinusoidal magnetization of magnetostrictive material is sensitive to the stress in the material. [1-4] The inverse behavior is that magnetostrictive material undergoes changes in magnetic susceptibility under strain (Villari effect). [1] This strain driven magnetic effect should lead to magnetic domain wall reorientation that will be detectable by acoustic emission sensors located at remote locations, but without the external magnetic field required for ferromagnetic materials. This effect should be strain rate sensitive, such that sensitivity increases with strain rate. Thus, application to a high frequency issue such as wing flutter - an increasingly serious concern for lightweight, flexible wings - will further enhance the potential for generation of inverse magnetostrictive AE. From a practical point of view, there is no method to easily detect strains at the site of unknown damage. One could use strain gauging or photogrammetry methods to map strains, but that would be difficult to know a priori where to always look for the high strain fields and therefore generally are impractical, plus that instrumentation may be impractical for a flight article. Methods such as conventional acoustic emission can detect the location of localized damage that is actively occurring in composites, but is commonly used to detect the growth of damage and is not definitive for strains. This concept would allow one to detect the high strain rates occurring in a component without having to know a priori the area that is actively failing or being subjected to high strains. Thus an engineer could discern whether his component is being subjected to abnormally high stresses. This would impact/benefit NASA testing programs under aeronautics and space if successful and possibly be applicable to an IVHM system for actual operations.

**References**

1. Kwun, H., and Burkhardt, G. L, "Electromagnetic Techniques for Residual Stress Measurements," *ASM Handbook, Nondestructive Evaluation and Quality Control*, v. 17 , p 159-163, (1996)
2. Chikaumi, Soshin, *Physics of Ferromagnetism,* 2nd Ed., International Series of Monographs on Physics, Oxford Univ. Press, New York, New York, pp343-381, (2002)

3. Gorkunov, E. S., Ul'yanov, A. I., and Khamitov, V. A., "Acoustic Methods: Magnetic Acoustic Emission in Ferromagnetic Materials. 3: Effect of Structural Changes on Magnetic Acoustic Emission (Review Article)," *Russian Journal of Nondestructive Testing*, Vol. 38, No. 5, 2002, pp. 376–397. Translated from *Defektoskopiya*, No. 5, pp 86–112, (2002)
4. Wilson, John W., Tian, Gui Yun, Moorthy, Vaidhianathasamy, Shaw, Brian A., "Magneto-Acoustic Emission and Magnetic Barkhausen Emission for Case Depth Measurement in En36 Gear Steel," *IEEE Transactions On Magnetics*, v. 45, n. 1, pp 177-183, (2009)